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INSTITUTING COMPUTERIZED WOVEN OR PRINTED TEXTILE DESIGNS WITH ADDED ADVANTAGE OF SHADE MATCHING

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INDIA

Technical report: Establishment of a computerized colour matching at BTRA*

Prepared for the Government of India
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Tak Fu Chong
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Vienna

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CONTENT

1. PROGRESS OF THE PROJECT ACTIVITY WITH REGARD TO COMPUTER COLOUR MATCHING AT BTRA

1.1 Computer Colour Matching Program

A computer colour matching program has been created based on the type of spectrophotometric match using the least square approach. The objective of this method is to minimise the spectral reflectance differences between the standard colour and the match prepared by a suitable combination of dyes. A correction program has also been created to correct for any difference in colour between the standard and the match. A correction matrix based on perturbing the tristimulus values with respect to dye concentrations is being used. All the programs were written in BASICA language.

1.2 Data Base Preparation

a) Disperse Dyes

About 50 disperse dyes from various dyestuff suppliers including Sandoz, Hoechst, Jaysynth Dye Chem., and Indian Dyestuff Industry were used for this detabase. The dyes were applied to texturised polyester fabric by means of a high temperature (130°C) beakers dyeing machine at 6 concentration levels up to 3% depth using a uniform dyeing method for all dyes.

b) Reactive Dyes

About 16 cold type reactive dyes (Procion M) from ICI were used for this database. The dyes were applied to cotton poplin woven fabric using a jigger by exhaustion dyeing.

c) Vat Dyes

About 17 vat dyes from the Indian Dyestuff Industry were used for this database. The dyes were applied to the cotton poplin woven fabric using a pad (pigment) jig (reduction) method.

These calibration dyeings were measured for spectral reflectance data using the Match Scan II spectrophotometer from 400 to 700 nm at 20 nm intervals. The measured data were being keyed into the computer colour matching program in the second stage. This information together with the corresponding spectral data for the standard allowed the program to predict recipes from various combination of the dyes in the database that may match the standard colour with varying quality.

1.3 Fastness Evaluation

All the dyes in the database were subjected to fastness evaluation with respect to washing and light fastness. For disperse dyes, sublimation fastness testing was also carried out. All the fastness testing results were found to be similar to that quoted by the dyestuff suppliers.

1.4 Compound Shades

Compound shades prepared from 2 dyes and 3 dyes combinations were used to test the accuracy of the colour matching software.

2. WORK PERFORMED AT BTRA

2.1 Lecture Series

An intensive integrated lecture series was conducted to members of the project team as well as scientists from other section of the BTRA. The following is the module topics.

a) Introduction to Colour.
b) CIE System of Colour Specifications.
c) Uniform Colour Space and Colour Difference Evaluation.
d) Colour Measuring Instrumentations.
e) Basic Principle behind CCM.
f) Algorithms for CCM.
g) Practical Implementation of CCM.
h) Precautions & Limitations of CCM.
i) CCM with Fibre Blends.

2.2 Group Discussions

Special topics of interest on various aspects of colour measurement and CCM were discussed with members of the project team, other members of BTRA as well as invited experts from the research institutes and the industry.

2.3 Demonstration and Practical Implementation.

Problems of CCM with fibre blends were demonstrated with specially prepared samples. Merits and dis-merits of alternative methods for CCM with fibre blends were intercompared. The Chong's method was presented in details with regard to both the principle and the practical implementation. Please refer to Appendix I for further details with regard to CCM with fibre blends. The project team had carried out the skeleton data base preparation under the expert's supervision. Demonstration on the identification of fluorescent samples as well as the evaluation of its true reflectance were carried out on the Match Scan spectrophotometer. In addition, a computer aided design software was also demonstrated to show its potential value in printed fabric design.

2.4 Public Lectures

Two public lectures were arranged by BTRA. They were "Measurement and Control of Colour for the Textile Industry" for members of the Textile Association and "Colour Measurement and Computer Colour Matching" for members of BTRA. An additional public lecture on "Advances in the Practical Applications of Colour Measuring System for the Textile Industries" was arranged by the Colour Group of India and the Association of Chemical Technology.

2.5 Technical Visits

To provide a better understanding of the local textile industries, BTRA arranged a series of technical visits to the following places.

a) Department of Chemical Technology, University of Bombay.

b) Wool Research Assocation.

c) Jay Group of Co.

d) The Hindoostan Spg. & Wvg. Mills Ltd.

e) The Standard Mills Co. Ltd.

Lecture and consultation was also given at some of the visits.

3. RECOMMENDATIONS

3.1 Recommendations on Evaluation of Calibration Data Bank

3.1.1 Coloration Process

It is advised to evaluate the repeatability of the individual dyeing process prior to any major production of calibration dyeing.

The repeatability of the dyeing process can be affected by the following factors.

a) Preparation of the process ingradients

(i) Variation in water quality such as hardness.

(ii) Variation in colorants and auxiliaries standardisation, moisture content, weighing and dispensing method.

(iii) Variation in substrate pretreatment, moisture content, weighing and dyeability.

b) Coloration Process

(i) Variation in process conditions such as L.R., pick up condition; pH, exhaustion dyeing curve, or fixation conditions.

(ii) Variation in aftertreatment such as washing off and drying conditions.

c) Machine

Variation in machine conditions such as variation in material running speed and flow and reversal of the coloration solution.

The repeatability of the dyeing process can be evaluated by repeat dyeing of both single shade and compound shade on a short term (e.g. weekly) basis and a long term (e.g. monthly) basis. The average of the colour differences measured between each repeat dyeing and the first dyeing gives a quantitative indication of the short term and the long term repeatability of the dyeing process. The result provides indication of the degree of confidence in preparing additional calibration dyeings with data that can substitute the earlier calibration dyeings which are only partially successful. The result also provides indication of the degree of confidence in the improvement in correction dyeing as well as for setting pass/fail tolerance. This work should also be extended to evaluate the correlation between the calibration database and that of the practical situation.

3.1.2 Colour Measurement Process

It is advised to evaluate the accuracy and precision of the Match Scan II spectrophotometer prior to the measurement of the calibration dyeings.

a) Accuracy

(i) Photometric Accuracy

This can be evaluated by setting the Match Scan II in the transmission mode and measure the spectral transmittance of standard filters (e.g. neutral density filters and amber filter) and comparing the results with the corresponding calibrated values.

(ii) Wavelength Accuracy

This can be evaluated by setting the Match Scan II in the transmission mode and identify the wavelengths of peak absorption of standard filters (e.g. didymium filter and holmium filter).

b) Precision

Here, we are interested in the short term as well as the long term repeatability of the Match Scan II spectrophotometer. The precision performance of the Match Scan II can be evaluated by repeat colour measurement of a set of stable colour standards such as the BCRA colour tiles on a short term and long term basis. The average colour difference measured between each repeat measurement and the first measurement provide a quantitative indication of the Match Scan II precision performance. For accurate computer colour matching, it is necessary to maintain the spectrophotometer precision throughout the period of the spectrophotometric measurements of the calibration dyeings, the standards, the laboratory corrections, the production trials and the final production.

If in the future, BTRA wish to communicate with their clients' spectrophotometric measurements. Evaluation of the reproducibility performance among both the BTRA's and the clients' spectrophotometers should be carried out in a similar manner.

BTRA may also wish to participate an international programme in the precision evaluation of colour measuring instrument organised by the MCCA in U.S.A. on a routine basis. In this programme, all participating members will receive identical stable colour material and the measurement results will be intercompared by the MCCA body and a report will be issued to each member. When BTRA having gained such experience, BTRA may wish to organise similar activity for its members within India at a much lower cost.

3.1.3 Accuracy of Calibration Dyeings

Good calibration dyeings information is a pre-requisite for accurate computer colour matching. In these calibration dyeings, one should include the highest concentration being practically used; select finer steps in the region of high concentration due to the non-linearity (K/S vs C) normally encountered in this region and the blank dyeing should also be carried out to determine the K/S values for the substrate. It is found that the highest concentration used by BTRA is normally 3% depth and the concentration increment steps are the same for all dyeings. It is recommended that BTRA should investigate whether they should vary this conditions with reference to the criteria given above.

The accuracy of the calibration dyeings can be evaluated by the following means.

a) Visual inspection
b) Inspection of spectral curves
c) Inspection of K/S Conc. plots
d) Self-prediction using other calibration

points

e) Control dyeings

BTRA has evaluated the fastness properties (washing, light and sublimation) of their selected dyes for calibration dyeings. BTRA should also evaluate whether the dyes are fluorescent or thermochromic. If the dye is fluorescent, it is a usual practice to avoid any fluorescent dye in the recipe unless it is absolutely necessary. This is because the Kubelka-Munk theory behind the computer colour matching does not account for any fluorescent emission. Further, the instrument set up conditions strongly affect the measurement result. The Match Scan II spectrophotometer is equipped with a tungsten hologen lamp which creat a lot of heat when illuminated into the sphere containing the colour sample. Those thermochromic samples may change their colours on exposure to heat during colour measurement and hence wrong data are being recorded.

3.2 Recommendations on the Match Prediction Program

3.2.1 Data Base Program

BTRA has written a program in BASICA to process the measured calibration dyeing data. The following points would be useful to improve its efficiency.

a) Colour Gamut Plot

For a given dye class, it would be convenient for the users to make dye selection if a L*, a*, b* plots is created for all the individual dyes around the standard.

b) K/S vs C Plot

The present K/S vs C plot is highly compressed. For more convenient inspection, the scale should be adjusted accordingly such as in the form of Log K/S vs Log C. This will also allow the lower concentrations to be inspected easily. With this plot, the deviation of the individual points from the linear regression fit can also be served as a diagnostic tool to assess the accuracy of the calibration dyeings.

c) Spectral K/S Plot

A program should be created to show the spectral K/S plot which is another useful diagnostic tool.

d) Database Classification

Since BTRA is going to provide central service for the local industries, the database will eventually grow to a very large population. Program should therefore be developed to classify the database according to substrate/process/dye class/user.

e) Data Base Editing

Program should be available to edit the database including the colorant price information.

3.2.2 Match Prediction Program

a) Basic Method

There are two important methods for computer colour matching i.e. the spectrophotometric match based on the least square approach and the tristimulus match based on vector addition with derivative weighting. For the commercial system for formulation, it is more common to use the method based on tristimulus match since the computation time is less and the matching principle corresponds closely to the practical situation where metameric matches are pre-dominant. This method may also be extended to yield matches of low metamerism by adding extra colorants to match the tristimulus values under another source. On the other hand, spectrophotometric match aims to minimise the spectral reflectance differences between the standard colour and the match without paying attention to the colour matching conditions such as lighting and the visual aspect as is being done in the tristimulus match method. It is recommended that BTRA should compare the performance of the present adopted method based on spectrophotometric match with that based on tristimulus match.

b) First Approximation

In the first approximation of the prediction for the recipe concentrations, BTRA uses the 1% depth of the database as the starting concentration to determine the specific K/S values. It is advised that BTRA should compare the results with the method based on the middle concentration of the calibration series.

c) K/S Data For Match Prediction

In BTRA's program, the mean specific K/S values of the calibration dyeings is being used for all subsequent recipe prediction calculation after the first approximation. It is recommended that BTRA should replace this method by a non-linear interpolation technique to relate the K/S quantities with dye concentrations for each set of calibration dyeings for better accuracy.

3.2.3 Correction Program

BTRA uses the correction method based on a correction matrix obtained by perturbing the tristimulus values by small changes in the individual dye concentration. The correction accuracy of this method can be improved by incorporating correction factors derived from recipe of the first match and recipe predicted for the first dyeing. This method was detailed in the lectures given to BTRA.

3.2.4 Others

a) Programming Language

BTRA's program is wirtten with IBM BASICA which is a BASIC interpreter. The program execution speed can be further improved by a more versatile language such as a compilable BASIC language.

b) Spectrophotometer Interfacing

At the present moment, BTRA's program is a standalone program that the spectral information measured from the spectrophotometer has to be keyed into the separate personal computer in order to execute the match prediction program. This will not only slow down the match prediction process but also creat unnecessary data input error. It is absolutely necessary that the 'Match Scan II' spectrophotometer be interfaced directly to the personal computer so that the program can be used to control the operation of the spectrophotometer as well as to access the measured information. In this aspect, both the interfacing software and hardware have to be sought from Milton Roy Ltd.

c) Program Format

At the final stage of the program development, the program format, which is at present command driven, should preferably be modified to a more user friendly format such as the menu driven type with various graphic presentations. Please refer to Appendix II for information on recent innovations of CCM system.

3.3 Recommendations on CCM central service implementation precautions

3.3.1 Variation in the Coloration Process Materials and Conditions.

Any variations in the coloration process materials and conditions between the primary calibration dyeings and the production dyeings will lower the accuracy of the match prediction. Common variables include the substrate dyeability, dye strength, water quality, auxiliaries, processing conditions and dyeing machineries. It has been found that minor variations could in general be corrected by means of the correction factors during the correction procedure. In the case of major variations, a new primary calibration dyeings has to be created for the new conditions for successful implementation of CCM. Examples are un-mercerized cotton versus mercerized cotton, filament polyester versus spun stapled polyester, exhaustion process versus continuous process.

3.3.2 Selection of Dye Recipe

A major advantage of CCM is the availability of large alternative recipes for matching the standard colour. For best prediction performance, one should avoid selecting recipes with dyes having properties deviating from the Kubelka-Munk theory. Examples are highly interactive incompatible dyes, fluorescent dyes, and thermochromic dyes. For best dyeing repeatability, one should select recipe with the primary colorants located close to the standard colour in the colour space. On the other hand, consideration should also be given to factors like price, fastness, and dyeing performance.

3.3.3 Repeatability of Coloration Process

Through a number of consultation meetings with the local textile processing factories arranged by BTRA, a major problem encountered is the poor repeatability of the coloration process due to the poor conditions of the dyeing machineries as well as the lack of precaution measures to control the coloration process. Poor repeatability implies practical deviations from the conditions used to creat the primary data base and hence lower the accuracy in match prediction. Remember the famous computer term 'GIGO'. Garbage information being fed to the computer system will eventually generate garbage ouput.

It is therefore absolutely necessary to educate the local textile processing factories with regard to the significance of the repeatability of the coloration process for successful CCM application. In this aspect, the following actions are recommended.

a) Demonstration

It would be worthwhile to carry out a project to show the local factories the effect of the coloration repeatability in calibration coloration, laboratory coloration and production coloration under controlled conditions and less controlled conditions, on the other hand, on the accuracy of CCM.

b) Model Factory

Select a local model processing factory with good process control performance for a specific coloration process and provide the necessary BTRA CCM service. Demonstrate the performance of the match prediction obtained alongside with the various unique advantages of the CCM system.

3.3.4 Data Security

Providing a central CCM service to members of the BTRA also means a large collection of various proprietary information range from the colorant prices to the details of the coloration process. Any leakage of such vital information to the third party will lead to serious consequence. BTRA should therefore pay specical attention to assure perfect data security during the implementation of central CCM service.

3.3.5 Seminars

Once the preparation work for the provision of central CCM service is ready, seminars on the following topics should be held for all BTRA members to familiarise them with details about the background and the operational aspects of CCM service.

a) Brief discussion on the principle of CCM.
b) Benefits of CCM.
c) Implementation of CCM.
d) Precautions and limitations of CCM.
e) Operation of BTRA's central CCM

service.

Seminars should be provided to both the management as well as the application engineers. However, more emphasis on the benefits and the limitations of CCM should be given to the management.

4. FUTURE PROSPECTS

When the BTRA's central CCM service approaches maturity, BTRA may consider the following activities to strengthen its technical position and service to members of BTRA.

4.1 Workshop Training

A regular workshop training course on 'CCM for the Textile Industry: Theory & Practice' be offered to the Indian textile industry. This course should be designed to introduce the basic principle of colour measurement technology and shows how to apply them in the colorant formulation with textile substrate. Attendees will get hands on experience with the colour and appearance measuring equipments as well as the practical implementation of CCM. A typical course should consist the following modules.

a) Introduction on colour.
b) Colour order system.
c) Colour difference calculations.
d) Colour measuring instrumentations and procedures.
e) Principle of CCM.
f) Practical procedure of CCM.
g) Limitations of CCM.
h) Selection of CCM systems.

i) Laboratory practice.

4.2 Monitoring Agent for Colour Measuring Instrumentation

There are at present about 50 CCM or standalone colour measuring systems in India. There are at present no organisation in India acts as a central body to monitor the reproducibility and accuracy of these colour measuring systems. BTRA may consider this role as a service to the India textile industry.

4.3 Integration of Textile Design System and CCM System

Various ways of different accuracy has been devised to communicate colour. These includes the use of general colour names, the use of colour order systems with a systematic collections of colour standards sampling the colour space and the use of CIE system. Of these methods, there is no doubt that the CIE system provides the highest accuracy. One drawback of the CIE colour specification system is the abscence of the real physical colour accompanying the numeric specifications. Otherwise, it would be useful as a colour development tool by designers for styling application for example. Such drawback has been, to some extent, overcome by the development of the coomputer aided design system to include the capability of colour synthesis and CIE colour specification for communication. Though such development is still in the preliminary stage yet the application value is tremendous as such system can be integrated to a CCM system for match prediction of selected colour design as well as for distant colour communication. Since the current BTRA project will eventually install a computer aided textile design system and a CCM sytem, further research in such integrated direction is worth pursuing.

5. CONCLUSION

A very active programme has been conducted during the one month expert mission to BTRA, India. The programme includes the progress review of the project team; an integrated lecture series on colour measurement and CCM; laboratory demonstrations; detail group discussions on the problems and solutions of basic colorimetry and CCM implementations as well as CCM program algorithm improvement. The programme is also participated by other members of the BTRA as well as invited experts. Special topic on both the theoretical and practical implementation of CCM with fibre blends is also rigorously treated. Both parties have agreed that the present UNIDO expert mission is a very fruitful mission.

APPENDIX I

THE ACCURACY

OF

COMPUTER COLOUR MATCHING

WITH

FIBRE BLENDS

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TECHNICAL FEATURES

The accuracy of CCM with fibre blends

By T.F. Chong

Computer Colour Matching has proved less accurate with blends than on single-component fibres. The problems are here examined, several methods discussed and a method proposed — paper presented to the recent Textile Institute Conference on Computers in the World of Textiles

Although the basic method of colour measurement was established more than half a century ago, only during the last 15 years has the application of colour measurement become particularly substantial and significant, thanks to the advance of computer technology and the revolution in equipment design. This has converted colour science from a scientific exercise in the research laboratory to a widely used commercial and industrial tool.

Among the applications of colour measurement, the use of computer colour matching (CCM) has played a very important role. In textiles and other fields the main objective of CCM is the calculation of colorant concentrations necessary for matching. Because of the speed and availability of the multiple choices of the predicted recipes, CCM can provide optimum and economic recipes, and is therefore more attractive than the traditional approach, based on trial and error.

Application of the CCM technique has been quite successful on single-component fibres. The basis of CCM for textiles relies on the use of Kubelk-Munk theory. The author has demonstrated this technique under controlled and less controlled conditions. A typical step by step approach of CCM is illustrated by the flowchart in Fig. 1. As time goes by, the textile market for single fibre substrate is gradually being replaced by substrates of fibre blends for the purpose of unique physical properties or for economic reasons. For example, we can improve handle, strength or lustre by blending the fibre concerned with other types of fibre. Normally, in the case of the coloration of fibre blends, the individual type of fibre has to be dyed with differential classes of dyes. This presents some problems to the CCM technique.

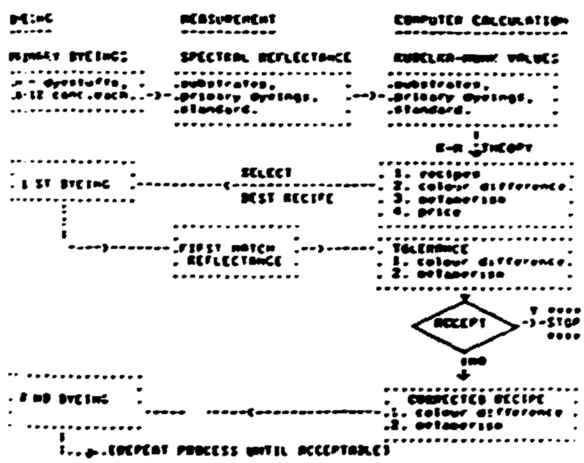

Fig. 1. Flowchart for computer colour matching

PROBLEMS OF CCM WITH FIBRE BLENDS

To produce a solid shade on a fibre blend, the individual components of the blend should be dyed to the same colour. The job of CCM is therefore to predict dye recipes separately for each fibre component, and the resulting colours of the dyed fibre components will match the standard colour. The accuracy of such CCM may suffer to a large extent however from certain possible sources of errors, besides the limitations experienced with single component fibre CCM.

- Variation in dyeing conditions: This is the difference in the dyeing conditions during the primary calibration dyeings of single component fibres and during the dyeing of a fibre blend, such as changes in liquor to goods ratio, pH and the effect of blocking by the other fibre component. To investigate this effect, two almost identical dyeings (same recipes and process conditions) on the cotton part of two forms of substrates using the same reactive dyes were carried out. The two dyeings differ only in that (a) in the first a polyester-cotton blend (65:35) knitted fabric was used, and (b) in the second dyeing a pure polyester knitted fabric and a pure cotton knitted fabric. Here also the ratio of the polyester to the cotton fabric weight was 65:35.

The raw fibres used in manufacturing the fabrics in (a) and (b) are the same, as are the spinning and knitting process. To measure the colour of the cotton part of the blend in (a), the polyester part was removed by a standard burn-out method with a solution of Potassium Hydroxide in Ethanol. Fig. 2 show the difference in the spectral reflectance factors for the dyed cotton parts in both cases.

• Cross-stainings: Normally the dye class used for the different components of the blend is different for optimum fastness and physical properties. As a result, cross-staining of the dyes on the opposite components of the fibre-blend occurs during dyeings. Hence this effect will not be accounted for during the preparation of the primary single fibre calibration dyeings.

Fig. 3 shows the spectral reflectance factor curves of the staining on the polyester part of the polyester-cotton (65:35) fabric obtained by dyeing the blends with increasing concentrations of a Reactive dye (Drimarene Dis Orange X-31G) and then removing the cotton part by treatment with sulphuric acid. In comparison with the top curve, which is the undyed polyester fabric, one can

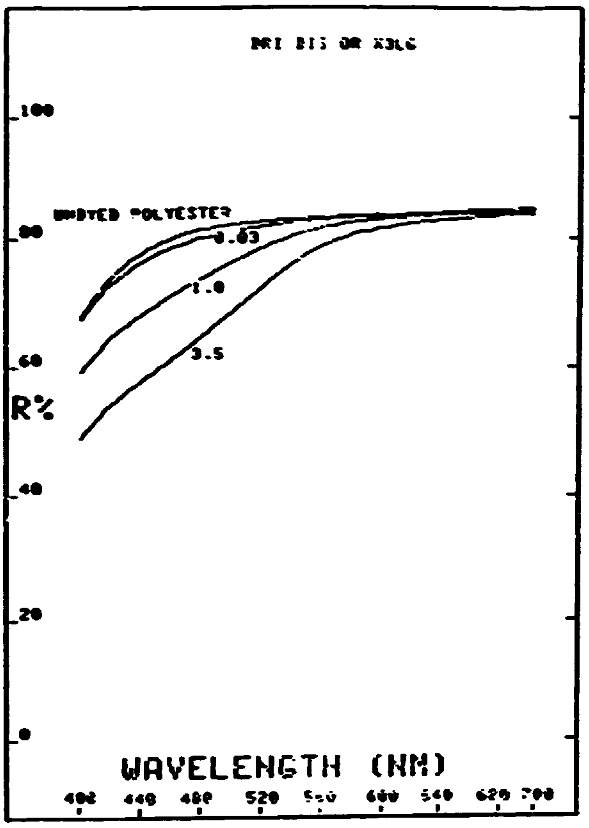

Fig. 3. Cross staining of reactive dye on polyester

easily observe the presence of the staining, and the degree of staining increases with increasing Reactive dye concentrations.

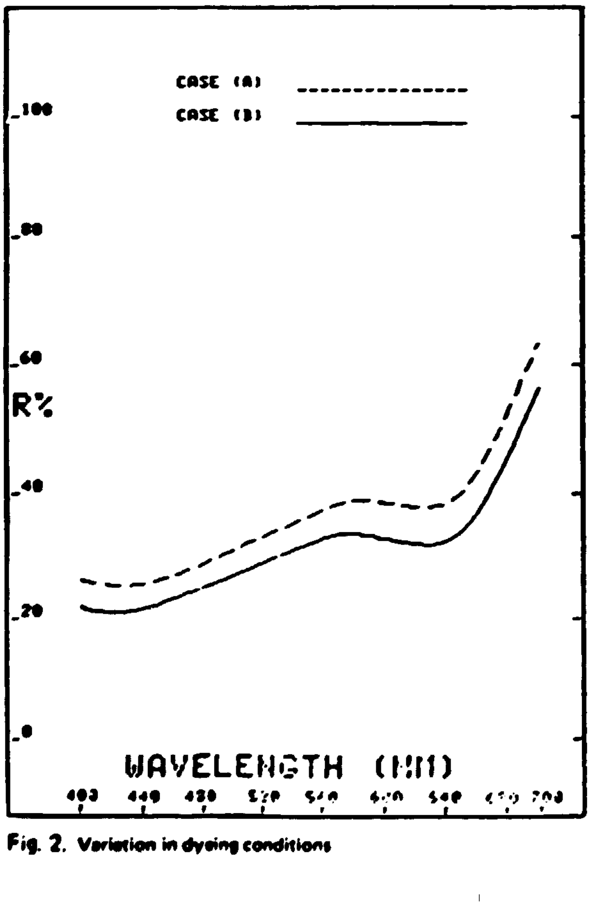

Fig. 2. Variation in dyeing conditions

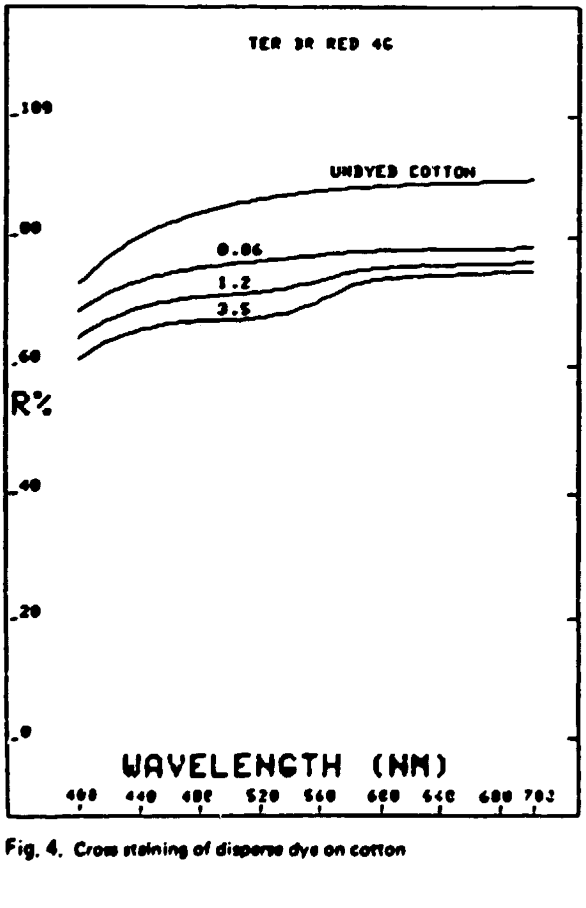

Fig. 4. Cross staining of disperse dye on cotton

Fig. 4 shows a similar situation, except that the staining is on the cotton part of the blends and is obtained by dyeing them with increasing concentrations of a Disperse dye (Terasil Br. Red 4G) and then removing the polyester part by treatment with Potassium Hydroxide in Ethanol.

• Effect of the fibre separation process: To evaluate the colour of the individual dyed components of the blends, a fibre separation process is necessary. To investigate whether the separation process has any effect on the colour of the dyed components, dyed fabrics of pure cotton and pure polyester were treated in the appropriate fibre separation solutions for the opposite fibres, i.e. dyed pure cotton in the burn-out solution for polyester and vice-versa.

Fig. 5 shows the spectral reflectance factor curves for a pure polyester knitted fabric dyed with a mixture of disperse dyes before and after the burn-out treatment. Fig. 6 shows similar information for the case of a pure cotton knitted fabric dyed with a Reactive dye. These curves show that the burn-out treatment for the dyed polyester has no effect on the colour change, while the burn-out effect on the dyed cotton is small.

However it should be emphasized that the dyed material should be properly aftertreated prior to the burn-out process. Furthermore, the separation process may affect the degree of staining on the other component of the fibre-blends. None of these sources of error would occur in the CCM of a single-component fibre.

In discussing the following methods for CCM with fibre-blends the polyester-cotton (65:35) blend is sometimes used as an example for illustration.

• Method 1: The primary calibration dyeings are created separately for the polyester component and for the cotton component, using suitable dye classes such as Disperse and Reactive dyes respectively. Then recipes are predicted separately for the polyester part and for the cotton part (most commercial CCM systems allow the recipes to be weighted by factors. In this case, the values of the factors depend on the expected degree of cross-stainings and hence on the dyers' experience. However this technique of trying to correct the staining effect is by no means reliable). The final recipes will be adjusted according to the blend ratio.

Any commercial CCM system can use this method. The drawbacks are that all the previously mentioned errors may exist. Furthermore the substrates used to create the primary calibration dyeings may not be the same as those of the components present in the blends, which leads to further problems. The accuracy of this method may be improved by selecting dyes of less staining power on the other component of the blend. However the selection of recipes is usually dominated by other factors such as fastness and economy.

• Method 2: This places emphasis on the calibration of the staining information. Basic information about the dyeing and staining behaviour of the individual dye is created. Then recipes are predicted for each fibre separately. These recipes and the primary staining information are then used to calculate the stain on the fibres. Finally the recipes are corrected for the contribution of the stainings. However the details of this method, which tries to correct the error due to cross-staining, were not published.

• Method 3: Matched pairs of two classes of dyes are preselected for each fibre component of the blend, i.e. members of the Disperse dyes for dyeing the polyester should match in colour with the corresponding members of the Reactive dyes for dyeing the cotton. Then recipes

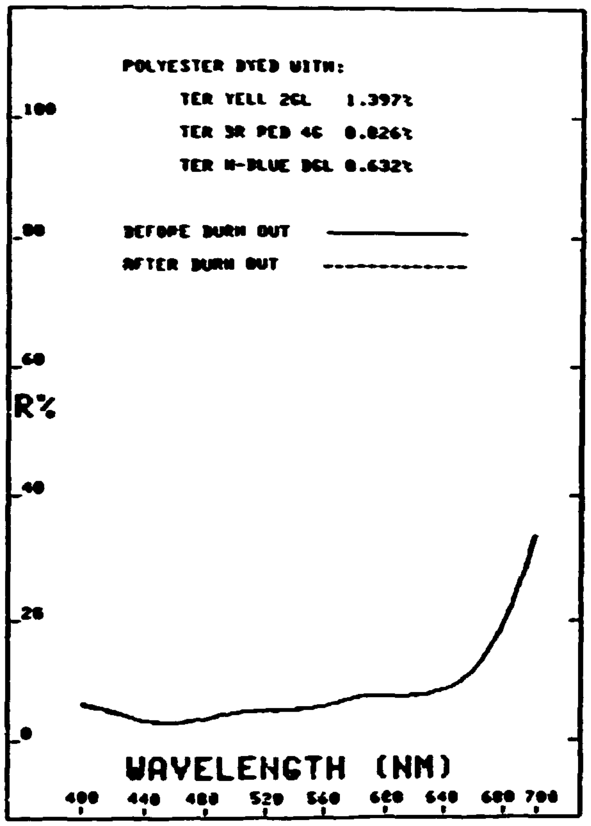

Fig. 5. Effect of burn out treatment on the colour of dyed polyester

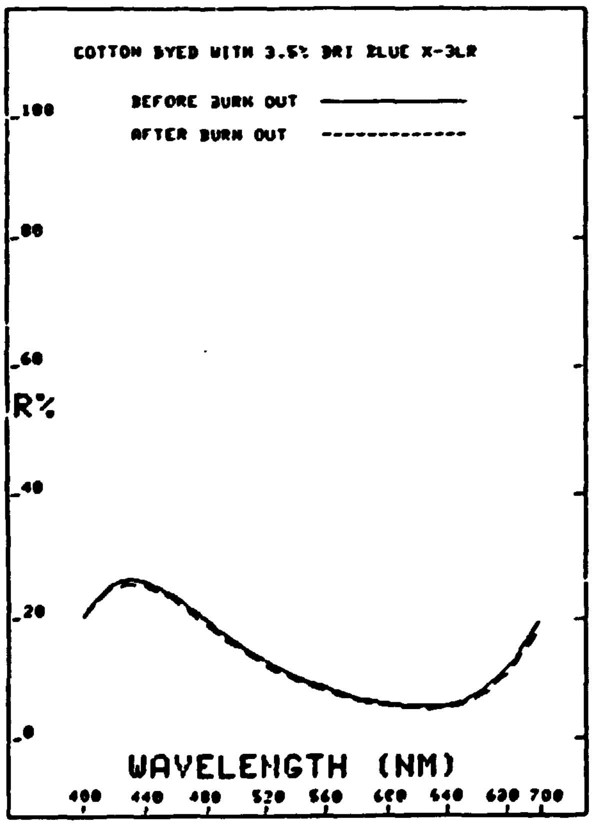

Fig. 6. Effect of burn out treatment on the colour of dyed cotton

are predicted for the individual component of the blend separately based on Method 1. The choice of recipes is limited to the extent that the two recipes for both components of the blend should contain the corresponding "matched pair" of the dyes.

A similar method is based on the use of pre-mixed dyes. The dye manufacturer supplies physically mixed dyes of two classes, and when applied to a certain fibre blend with a certain blend ratio they will dye both components to the same colour.

This method still has the possible errors mentioned under "Problems of CCM," though the cross-staining may be corrected more easily during the correction stage. Furthermore the choice of recipes, which is an important attractive feature of CCM, is very limited. On the other hand the use of premixed dyes may reduce the error due to differences in the dyeing conditions, since the calibration dyeings can be developed directly onto the fibre-blend. Yet the use of this method has other similar problems, and is limited to a specific application process and blend ratio. Hence Method 3 will not be tested against other methods.

PROPOSED METHOD FOR CCM WITH FIBRE BLEND

In this method the calibration dyeings are created directly onto the blend with one dye class, and then this process is repeated for the other dye class. The undyed component of the blend is removed by an appropriate separation process; they are then used as the corrected primary calibration dyeings. Then recipes are predicted separately for the individual component of the fibre-blend, using the corresponding corrected primary calibration dyeings. The recipes predicted by this data bank are used to obtain the stained samples of each fibre component. Finally recipes for each fibre component are adjusted for this staining effect.

This method tries to minimise the errors due to variation in dyeing conditions (e.g. blocking effect) and the cross-staining effect. Furthermore the pure fibres of the individual component of the fibre blend, which is not always available, are not required for the preparation of the calibration dyeings.

The preparation of the data bank to evaluate the accuracy of Method 1 and the Proposed Method entailed:

- Preparation of textile substrates: Pure polyester fibres and pure cotton fibres were spun into polyester yarn and cotton yarn respectively. The same polyester and cotton fibres were also mixed in the ratio of 65:35 and spun into a blended yarn. The three kinds of yarn (30s each) were individually knitted into plain fabrics. They were then properly pretreated.
- Calibration dyeings – Disperse dyes: Three Terasil disperse dyes were used to prepare the calibration dyeings. These include Ter. Yellow 2GL, Ter. Br. Red 4G and Ter. Navy Blue BGL. Calibration dyeings were carried out for these dyes at suitable concentration levels using the Linitest Laboratory dyeing machine. The liquor to goods ratio was 12:1. All the chemical auxiliaries employed were laboratory-made. The dyeings were carried out for both the pure polyester and the blended fabric, the method being shown in Fig. 7.
- Calibration Dyeings – Reactive dyes: Four Drimarene Reactive dyes were used to prepare the calibration dyeings. These include Drimarene Rubinole X-3LR, Drimarene Discharge Orange X-3LG, Drimarene Blue X-3LR and

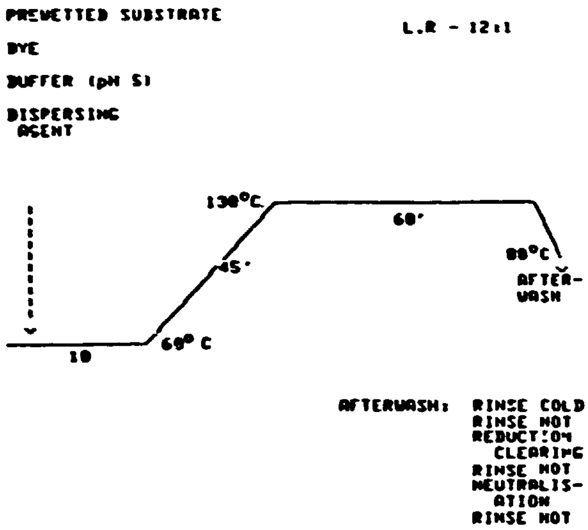

Fig. 7. Dyeing method for disperse dye on polyester

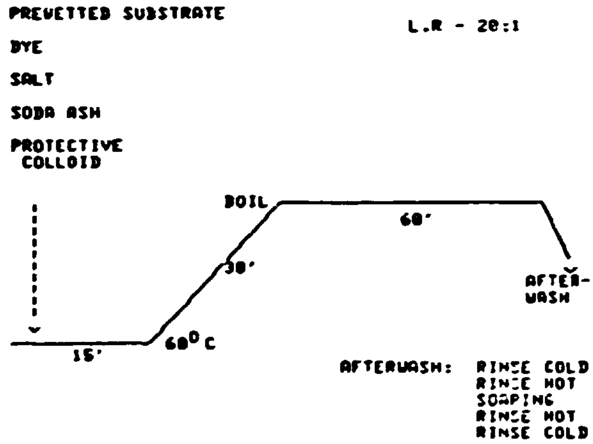

Fig. 8. Dyeing method for reactive dye on cotton

Drimarene N-Blue X-RBL. The preparatory work is similar to that of the Disperse dyes. The dyeing method is shown in Fig. 8.

- Skeleton calibration dyeings: The calibration dyeings carried out on the polyester-cotton blend were subjected to a fibre-separation process to remove the undyed component of the blend. Sulphuric acid (70%) was used to burn out the cotton component, while a solution of Potassium Hydroxide in Ethanol was used to burn out the polyester component.

COLOUR MEASUREMENTS

The Zeigs RFC3 spectrophotometer was used for the measurement of the spectral reflectance factors at 20 mm intervals in the range 400 to 700 mm. It is calibrated with the Merck Barium geometry. The specular component was included. Each sample was measured several times at different areas and directions and at complete opacity.

Figs. 9, 10 and 11 show typical calibration dyeing curves for the Disperse dye (Ter. Br. Red 4G) being applied on to the polyester, the blend and the dyed skeleton respectively. Similar information is given in Figs. 12, 13 and 14 for the Reactive dye (Dri. Discharge Orange X-3LG).

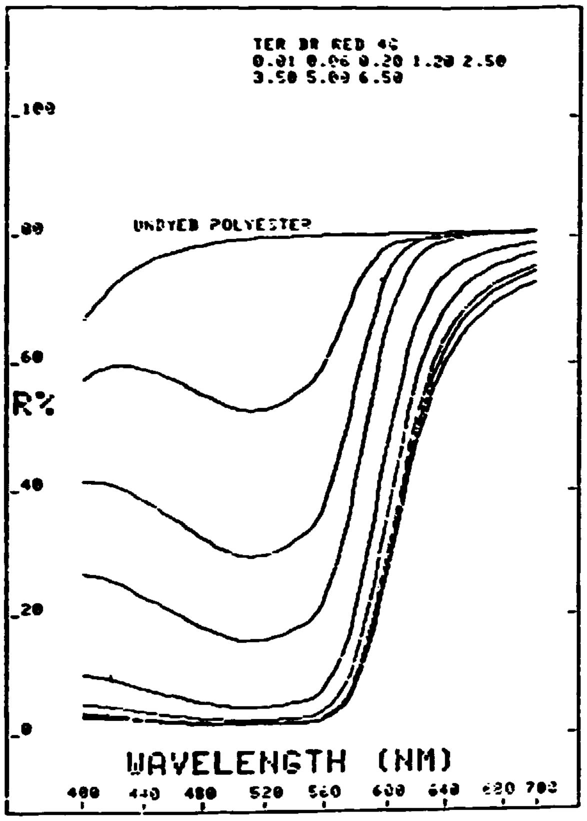

Fig. 9. Calibration dyeings of a disperse dye on pure polyester

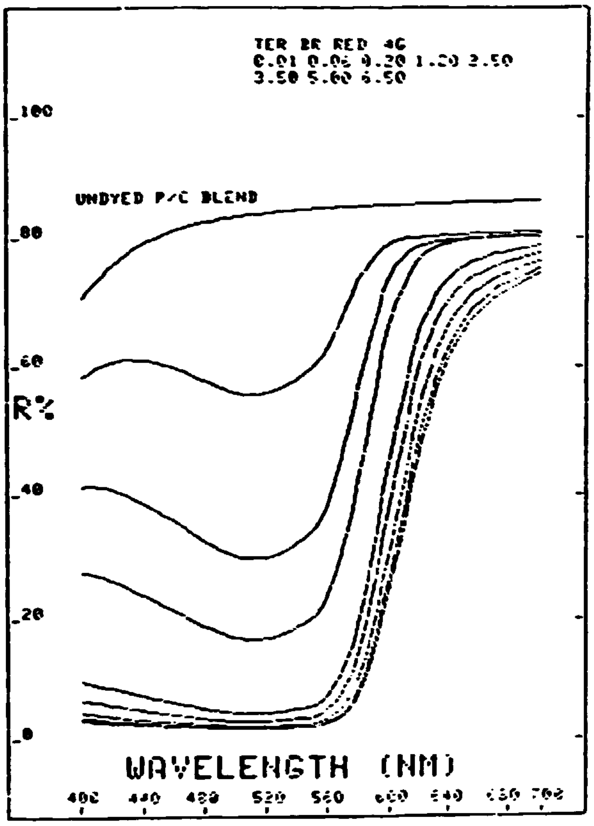

Fig. 11. Polyester skeleton calibration dyeings of a disperse dye on P/C blend

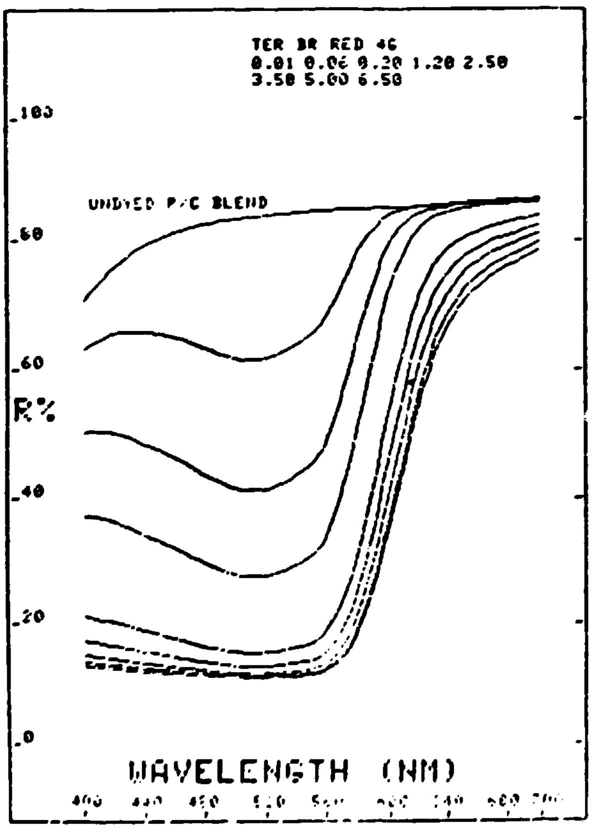

Fig. 10. Calibration dyeings of a disperse dye on polyester-cotton blend

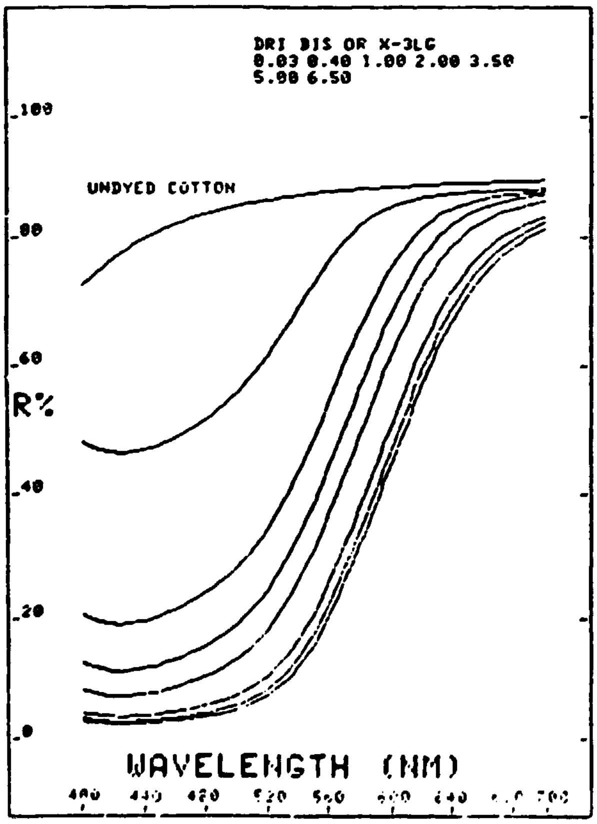

Fig. 12. Calibration dyeings of a reactive dye on pure cotton

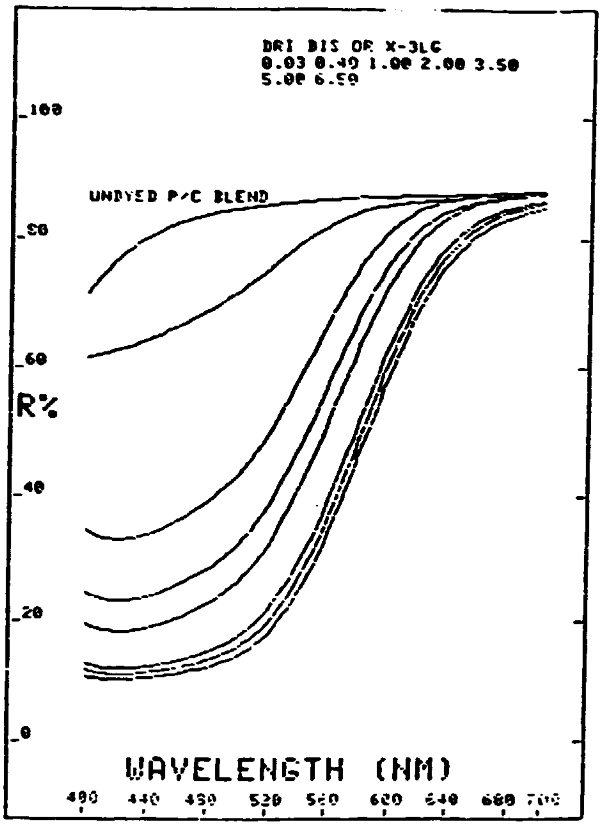

Fig. 13. Calibration dyeings of a reactive dye on P/C blend

COLOUR STANDARDS FOR MATCHING

Four colour standards (A-D) were prepared; their spectral reflectance factor curves are given in Fig. 15.

Based on the Kubelka-Munk (single constant) theory and the established calibration dyeings data bank, formulations for both components of the polyester-cotton blends were created according to Method 1 and the Proposed Method to match the four colour standards. Dyeings were carried out onto the blends with a normal two-bath two-step process using the same dyeing conditions as of the calibration dyeings. Finally, colour differences (ΔE^*ab) were measured between the colour standards and the corresponding dyed colours of the blends. These colour differences provide some indications of the degree of accuracy of the methods.

The spectral reflectance factor curves of the colour standards and their corresponding matchings for each method are given in Figs. 16, 17, 18 and 19 for the standards A, B, C and D respectively. Table 1 summarises

Table 1. Accuracy of CCM on Polyester-Cotton Blend Using Method 1 and the Proposed Method

	Std A	Std B	Std C	Std D	AVE
Proposed Method	0.4	3.8	2.4	2.2	2.2
Method 1	3.5	5.5	3.7	1.7	3.6

Note: The colour differences presented are based on the 1976 Cielab Equation, Std. ILL. D65 and 1964 10 degree standard observer.

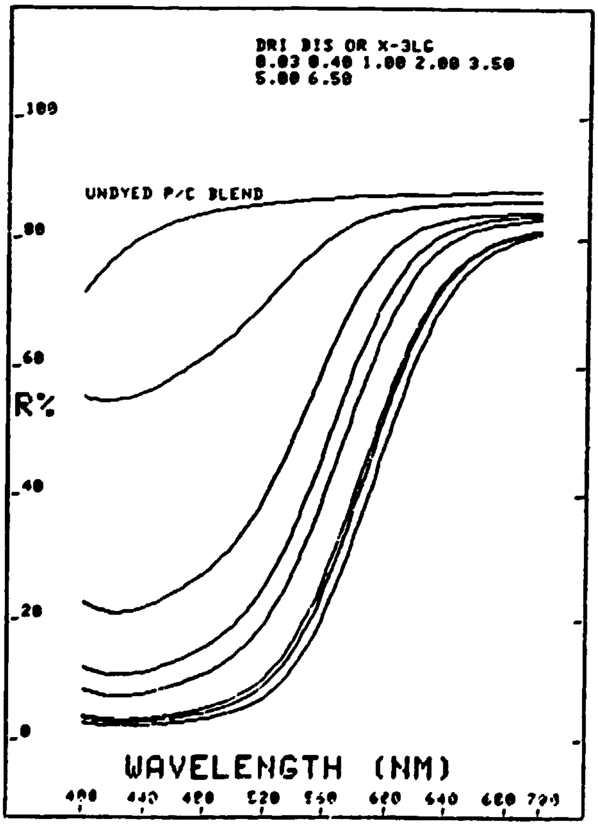

Fig. 14. Cotton skeleton calibration dyeings of a reactive dye on P/C blend

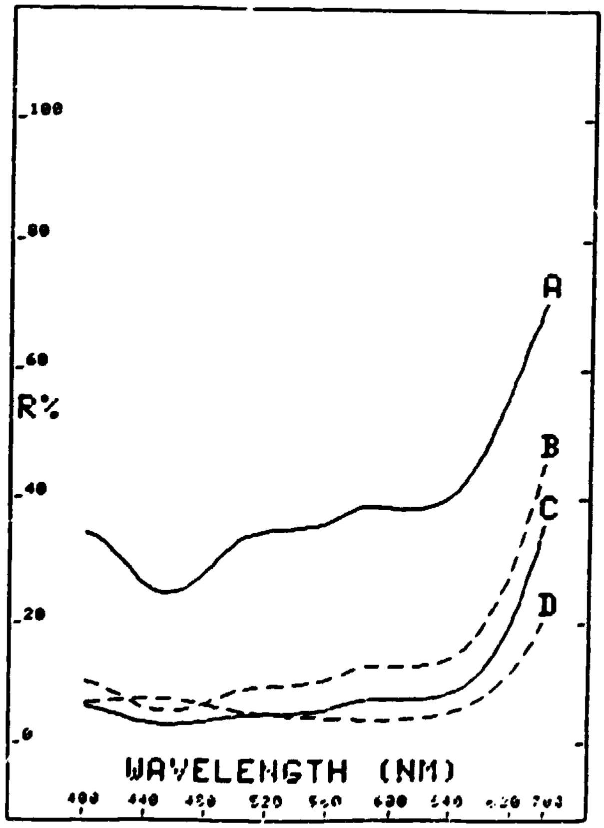

Fig. 15. Spectral reflectance factor curves for colour standards A-D

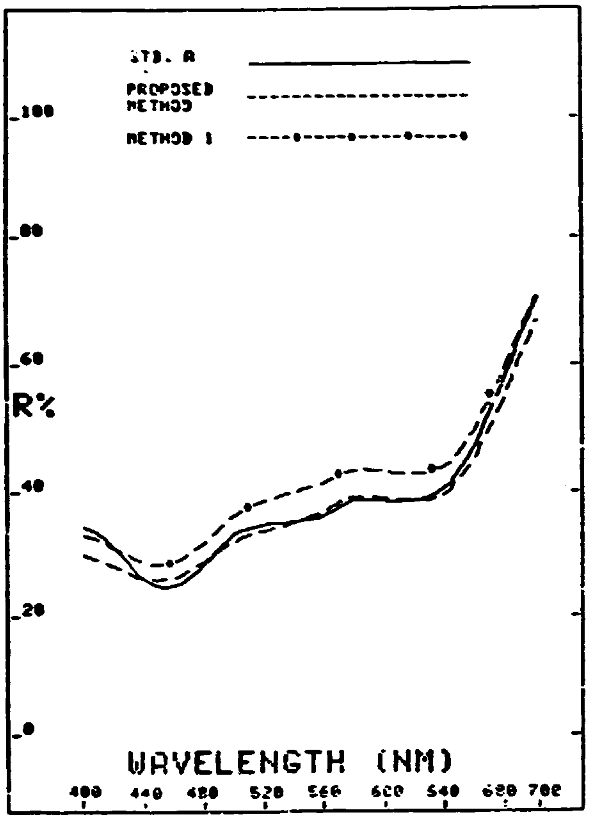

Fig. 16. Spectral curves of the matchings by the Proposed Method & Method 1 for std. A

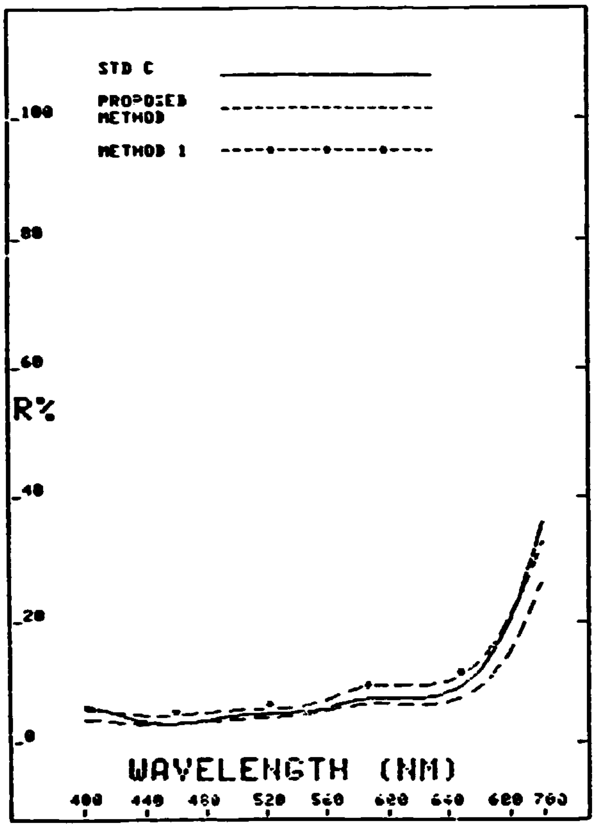

Fig. 18. Spectral curves of the matchings by the Proposed Method & Method 1 for std. C

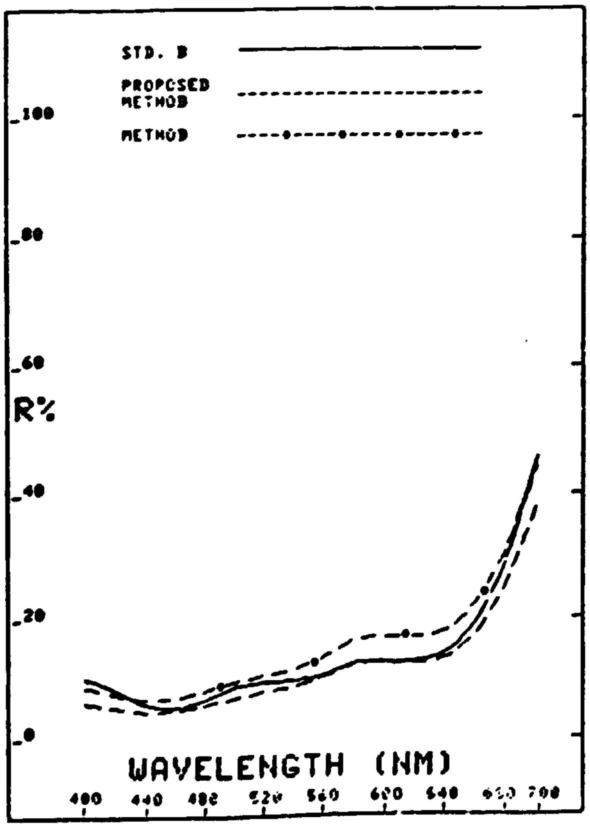

Fig. 17. Spectral curves of the matchings by the Proposed Methods & Method 1 for std. B

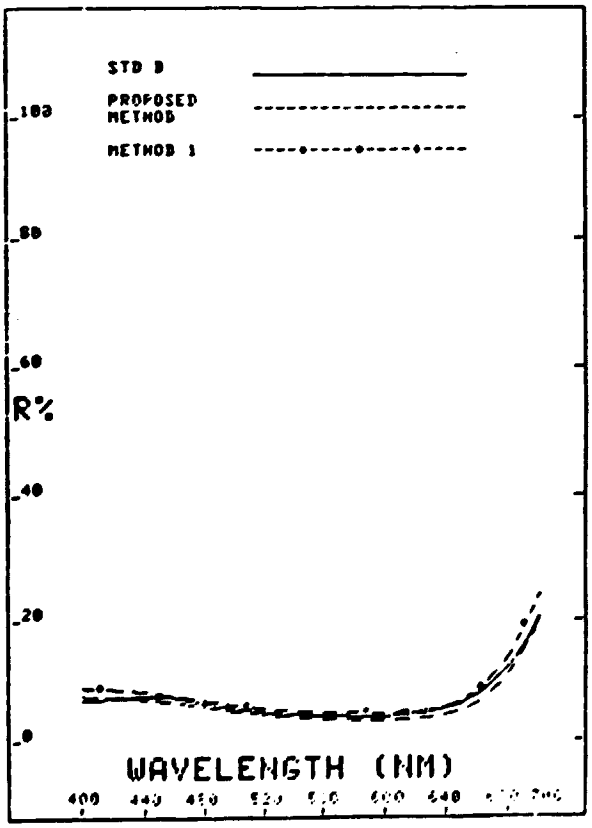

Fig. 19. Spectral curves of the matchings by the Proposed Method & Method 1 for std. D

the colour differences of these matchings, for each method using the 1976 CIELAB colour difference equation, standard illuminant D65 and 10 degree standard observer.

The average colour difference between the standards and the matchings based on the Proposed Method is 2.2 units, while the corresponding figure based on Method 1 is 3.6 units. The poorer result obtained by Method 1 is expected, as this method suffers from all the drawbacks mentioned in section 2, whereas the major drawback of the Proposed Method is the error involved during the fibre separation process. Table 2 compares the two methods with regard to the possible sources of error.

The improvement in the accuracy of the Proposed Method over Method 1 is expected to be more significant in practice. This is because in utilising Method 1 it is necessary to create calibration dyeings on the pure single component fibres which should be identical to the individual component of the fibre-blend for best performance. This point has been taken car- of for this project. However it would be very difficul- .. practice, if not impossible, for the dyer to obtain the pure fibres of the individual component of the blends that he is told to colour. ■

Table 2. Possible sources of errors

Method	Variation in dyeing conditions	Cross-stainings	Fibre separation process	Variation of the fibres used for calibrations from that of the fibre-blend components
1	Possible	Possible	Possible	Possible
Proposed	Less possible	Less possible	Possible	Not possible

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APPENDIX II

ADVANCES

IN THE PRACTICAL APPLICATIONS

OF

COLOUR MEASURING SYSTEM

FOR

THE TEXTILE INDUSTRIES

Advances in the Practical Applications of Colour Measuring System for the Textile Industries

Dr. T.P. Chong

1. INTRODUCTION

The foundation for quantitative colour specifications is not available until the early thirties. In 1931, the International Commission on Illumination (CIE) had recommended a system(1)(2) for the specification of colours. Nevertheless, this method was not popularly used in the commerce and industries mainly because of the complex procedures involved. However, with the advances in computer technology, better understanding of the colour science, and the revolution in equipment design, the application of colour measurement technology in the commerce and industries has now been widely accepted. This paper summarises the major developments in the colour measuring system since the time of early 70's when the colour sensor is interfaced to the computer. The impact of such developments on the practical applications in the textile industries is discussed while the future prospects of the role of colour measuring system in the direction of large scale integration of colour production system is highlighted.

2. COLOUR MEASURING SYSTEMS

A colour measuring system consists of the colour sensor, the computer hardware and the computer software. It is further divided into two major types, the spectrophotometer type and the tristimulus colorimeter type. The fundamental data being measured by the former is reflectance factors or spectral transmittance while the later measures for CIE tristimulus data directly. These devices are now interfaced to computers for the purposes of equipment control, data processing, data transfer, data storage and data communication.

3. DEVELOPMENTS

3.1. Colour Measuring System

The major developments in the structure of colour measuring system since the 70's fall in a number of areas including the illuminating system, the sample compartment, and the detector system.

The conventional system utilises the tungsten lamp or the continuous light emitting xenon arc lamp. In some instruments, the tungsten halogen lamp is now augmented with an uv lamp in order to boost up its uv power to provide a better fit to that of the CIE D65 illuminant for the evaluation of fluorescent samples. On the other hand, the relatively less stable Xenon source is now in the form of a pulsed xenon arc lamp with a more compact size.

Integrating sphere remains the popular sample compartment. Some equipment manufacturer claim better repeatability by using diffuse/exact 0 degree geometry instead of the more conventional diffuse/8 degree geometry. On the other hand, 0 degree/45 degree circumferential viewing is also used for textured sample measurement. Traditionally, the integrating sphere interior wall is coated with barium sulphate which has good diffusing and relecting power though it is easily contaminated. Recently, it has been replaced by Halon which has similar diffusing and reflecting properties yet the maintenance is easier. It is difficult to measure small samples using the older type equipment because of the large sample port and area of view. Now, most equipments provides optional small area view lens for the measurement of very small samples of up to 1/8 inch diameter. With special optical attachment, one can reduce the measurement area to 2 x 2 micrometers for special application.

The traditional photomultiplier detector has been slowly replaced by the tiny size solid state silicon-diode photodetector array which is positioned accurately in the dispersed spectrum so that each detector responds to a specific small band of wavelengths. This has made possible the measurement of the entire spectral data simultaneously for the spectrophotometer and thus increasing the measurement speed drastically. The quick measurement speed is also important for the development of another class of equipment known as non-contact remote colour measuring system which can monitor the production colour on-line. With the advances in the technology of computer and instrument design, the size of the equipment has been reduced to that of a portable type which would be useful for field measurements.

These developments of the colour measuring sensors coupled with the revolution in computer power and versatility as well as their integration has led to a significant advance in the performance of the colour measuring system in terms of speed, accuracy and precision as reported by Billmeyer[3] and Robertson[4]. The gains in the system performance has great impact in its application area.

3.2. PRACTICAL APPLICATIONS

The breadth and the depth of the practical applications of the colour measuring system has increased considerably since the 70's. This is primarily the results of consistant advances among the information technology, the equipment design as well as the science of colour. In the 70's or earlier, the basic application falls in the area of computer colour matching. With the progress in science and technology, the applications spread horizontally into a number of areas including the colour quality monitoring and colour communication. At the same time, the individual application area also develops vertically in depth.

3.2.1 Computer Colour Matching

Although the fundamental concept of match prediction is laid down in the early 30's. However, the first commercial computer colour matching device is not available until 1958. This was the Colorant Mixture Computer (COMIC) which was developed by Davidson and Hemmendinger[5]. It had not gained extensive popularity largely because of its speed and flexibility as the computer is an analog version. In the 60's, digital computer became available and most leading colorant makers installed their system of CCM to service their customers as few of them can afford the cost of computer. These systems include the Instrumental Match Prdiction system of the Imperial Chemical Industry[6] in 1963, the Computer Color Matching system of American Cyanamid[7][8] in 1963, the Automatic Recipe Formulation & Optimalization system in 1964 of Sandoz, Programmed Match Prediction Technique of Du Pont in 1965, and the computer colour matching system of Ciba-Geigy[9]. However, these systems usually have the disadvantages of poor accuracy as the fundamental colorant calibration data were not made by the user and the colorant formulations generated were restricted to one colorant maker. Furthermore, degree of metamerism was not indicated for certain system. In the late 60's, time sharing CCM system were available in which user can develop their own data bank. These include the systems developed by the General Electric, IBM, Beckman Instruments, and the Applied Color System. So far, all these CCM systems are abridged i.e. data measured on the colour measuring equipment cannot be transferred to the computer directly. In the late 70's, CCM and other practical colour measurement applications has gained wide popularity because of the availability of relatively low cost mini-computers which are interfaced directly to the colour measuring equipments. At this time, many users can afford to have such an integrated in house CCM system with improved speed and accuracy.

In the early 80's, CCM has reached a new stage with the introduction of IBM or IBM compatible personal computers (PC). The interfacing of the colour measuring sensor with the PC means a significant decrease in the cost of the CCM system such that the CCM system is no longer a privilege of the medium to large dyehouses but can also be afforded by the smaller dyehouses especially in the developing countries or for those companies which have already owned PC. Because of the open architecture of the personal computer and the affordable price, the system becomes more versatile as there are thousands of third party softwares and accessories prepared for all kinds of applications in virtually any aspects. At the same time, the CCM system becomes much more compact in size. On the other hand, the drawbacks with such system are the relatively smaller CPU memory and storage capacity, slower in speed, as well as the poorer performance in network environment in comparison with the minicomputer version. This has rendered the PC type CCM system more or less a personal or standalone system where as the minicomputer type being the multi-workstations system with a much stronger performance in network environment. In 1987, the new IBM PS/2[10] or PS/2 compatible personal computer being supported by the OS/2[10] operating sytem (released in 1988) has definately narrowed the gap between the two versions of the computer systems significantly. Already, a number of equipment manufacturers have already upgraded their PC type CCM system into the PS/2 version and the gain in computer performance is evident. It is expected further innovations in the application of such system are coming along particularly in the direction of integration with other related application system.

While the computer technology advances, innovation in the CCM software also happens. The most evident is that the software is written in a much more user friendly manner usually in a menu driven format with plenty of help messages and colourful graphic interpretations that is not available in the early 70's. Other innovations are summarised in the following.

a) Storage and retrieval of colour standards alongside with relevant useful information.
b) Input of standards can be achieved by a variety of methods.
c) Assignment of performance factors for individual dyes for correction of strength variation.
d) Creation of suitable dyeing groups of compatible dyestuff, substrate and dyeing process for formulation.
e) Varieties of graphical presentations for the assessment of the measured calibration dyeings.
f) Automatic queued match predictions of combination of variable number of dyes per recipe based on the pre-assigned standards, dye candidates, and tolerances.
g) Manual formulation or correction with support of graphical presentations.
h) Formulation for the use of surplus dyes or materials.
i) Correction can be achieved by using original dyes and new dyes or their combinations.
j) Special colour matching program e.g. for blending of various coloured fibres for matching.

The use of CCM is so popular that such service has reached the store level in some regions. On the other hand, though the technique of CCM has been practiced over 30 years, yet there are still a number of limitations[11]. The major limitation being the poor accuracy of CCM for fibre-blends coloration[12] and for coloration with fluorescent colorants[13].

3.2.2. Colour Quality Monitoring

In the early 70's, the features of using colour measuring sytem for colour quality monitoring is basically limited to the comparison of standard and samples with respect to the caluated colour differences or its individual component differences using a variety of colour difference formulae. Since the recommendation of the CIE CIELAB colour difference formula in 1976, the use of this formula has become a standard for the textile industry. However, the situation has reversed in the early 80's that a number of proprietary formulae as well as some published new formulae which claimed to have better performance are being introduced. Innovations in the colour quality monitoring area is summarised in the following.

a) Colour pass/fail

- multiple samples can be evaluated against the standard colour with various combination of preset tolerance of colour difference or combination of its components with the support of graphical presentations.
- storage and updating of pass/fail tolerances which can be adapted to particular situation such as for specific customer or product.
- automatic generation of pass/fail tolerances based on proprietary data base.
- direct integration with the formulation correction module.
- statistical interpretation of pass/fail results.
- pass/fail classification according to recommendation of professional body e.g. SAE J1545.

b) Colour sorting of dye lots

The prevailing format of colour sorting is based on the Simon method known as the "555" system(14) but variations in the shape of the individual colour cells in the 555 system and the colour difference formulae for sorting have been introduced. Other innovated features are the possibility of the reduction of the number of the sorted lots by selecting a new standard or an optinum standard and varying the tolerances without re-measurement. In addition, cross check under secondary illuminant is possible for the detection of metamerism.

c) Special indices
Special indices have been developed to assist in the evaluation of the visual qualities of samples such as the various whiteness indices, yellowness indices, and metamerism indices.

d) Dye strength evaluation
Standard procedures for relative dye strength evaluation has been worked out by some dyestuff manufacturers(15) and the Inter-Society Color Council(16). Determination of the residual colour difference is also possible after the adjustment of strength at equality(15).

e) Fastness rating
Methods have been developed for the evaluation of the change in colour[17] and degree of staining[18] for the determination of fastness ratings by means of colour difference measurements. However, the success of these methods remains to be tested.

f) Colorant solution evaluation
Spectrophotometer equipped with transmission measurement has been traditionally used to evaluate colorant solution for quantitative analysis. Further developments in both the quantitative and qualitative analysis have taken place. This includes the monitoring of dye exhaustion characteristics[19], the determination of solubility and solution stability of water soluble dyes[20][21], the evaluation of relative colorant strength based on solution measurement[22], and the evaluation of formaldehyde content[23]. On the other hand, it has also been used for the investigation of dyeing mechanisms[24].

3.2.3 Colour Communication

Various ways of different accuracy has been devised to communicate colour. These includes the use of general colour names, the method of designating colours developed by the Inter-Society Color Council and the National Bureau of Standards[25], the use of colour order systems with a systematic collections of colour standards sampling the colour space such as the Munsell notations[26], and the CIE system[2]. Of these methods, there is no doubt that the CIE system provides the highest accuracy. Furthermore, one can easily use the CIE colour specifications for quick distant communication via international telecommunication system. One drawback of the CIE colour specification sytem is the abscence of the real physical colour accompanying the numeric specifications. Otherwise, it would be useful as a colour development tool by designers for styling application for example. Such drawback has been, to some extent, overcome by the development of computer aided visual colorimeters[27][28] for colour synthesis and communication (Computer Aided Colour Communication "CCC") that complement with the Computer Aided Design system (CAD) nicely. The CCC provides a tool for inter-conversion between the displayed colour and the CIE colour specifications. However, the success of this method requires further research due to a variety of technical and visual observation problems[29].

3.2.4. Other developments

On-line monitoring of the colour production quality of the continuous dyeing range is also another important development. Such system allows real time assessment of the colour variation from the standard and statistical treatment of the measurements provide trending data that signaled an approach to out of tolerance limits. Important features of such monitoring device is the fast measurement speed, non-contact capability, good depth of focus, and large area of view.

As the computer technology advances, better local and remote networking for the colour measuring system is possible. Local networking can support as many as 12 working stations. Networking may also be used to integrate the CCM system with the other important units of the entire colour production process.

4. FUTURE PROSPECTS

In general, the development in the colour measuring equipment is quite discrete and standalone. During the growth of the colour measuring equipment, other coloration related equipments have also been developed. These include the Computer Aided Design system (CAD), the Computer Aided Colorant Dispensing system (CCD), and the Computer Aided Process Control system (CPC) which includes both the automatic coloration and the colour monitoring devices. To some extent, partial integration of these devices has already been developed particularly in the laboratory environment. In the next decade, technology development will be in the direction of total integration for the purposes of improving accuracy, precision, efficiency as well as quick response. The colour of the design obtained from CAD-CCC will be transmitted to the CCM where the colorant formulations will be predicted and the selected recipe will pass onto the CCD for dispensing the required amounts of colorants and chemicals into the production system where the CPC will monitor and control the entire production process. On the other hand, Production Management System (PMS) for the coloration and finishing industry is available and is another potential area for integration. Such an integrated system can communicate with another similar system or just a CAD-CCC device at another location via computer network or telecommunication system. Figure 1 shows the concept of a large scale integrated colour production system which can interface to other similar systems.

5. CONCLUSION

In less than half a century, colour measuring equipment has evolved from a standalone unit to a computer interfaced system and is moving in the direction of total integration. At the same time, the application environment has also evolved from the research laboratory to the industry level and has now reached the retail level. The target is to let the usefulness of such device to reach the general public in direct contact. Such evolution behavior is very similar to the case of computer. With the advance in science and technology, progress shall continue to move further along these two directions in the next decade.

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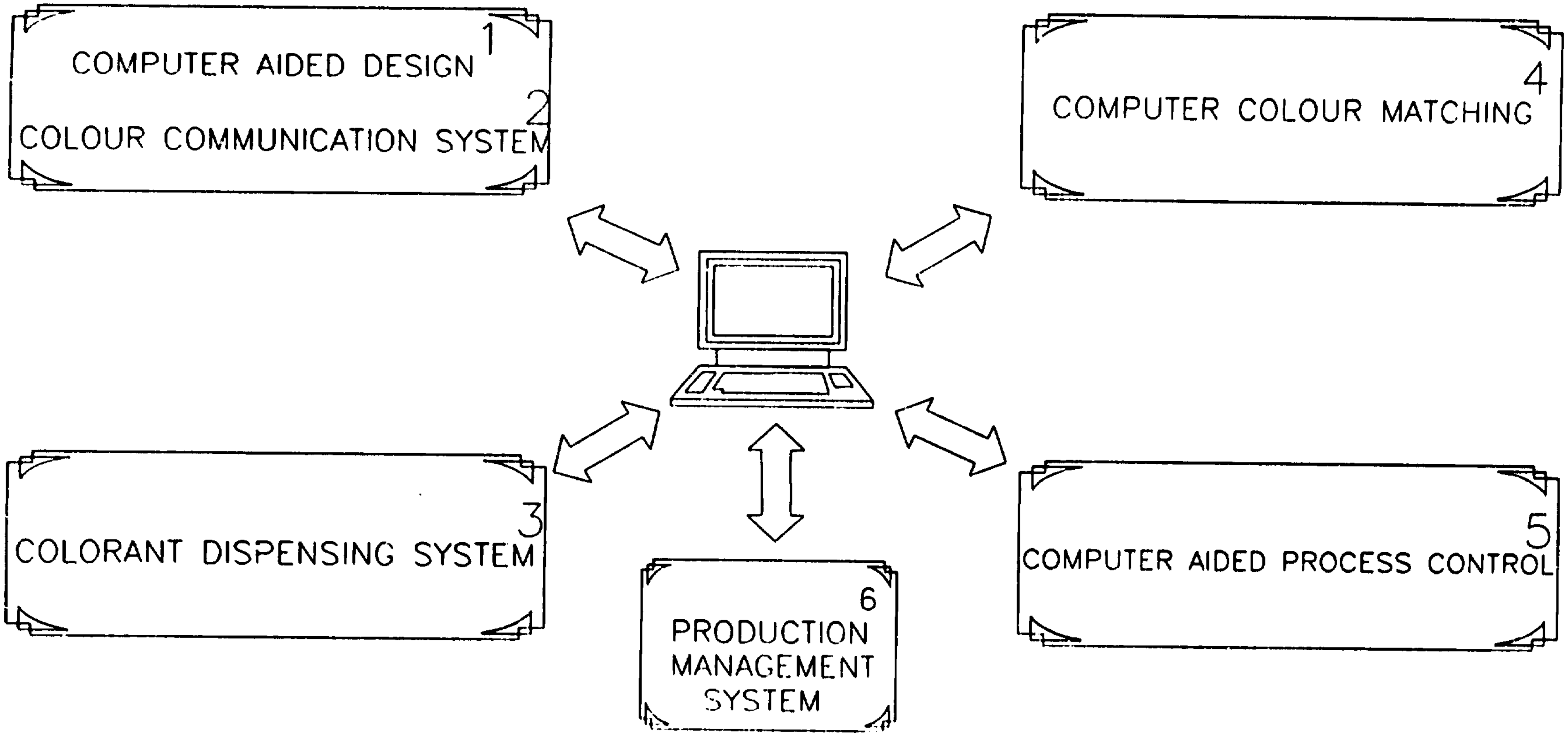

1. A SYSTEM TO ASSIST PRODUCT DESIGN
2. A SYSTEM TO ASSIST THE COMMUNICATION OF COLOUR IMAGES WITH QUANTITATIVE SPECIFICATIONS
3. A SYSTEM TO ASSIST COLORANT FORMULATIONS
4. A SYSTEM TO DISPENSE THE REQUIRED AMOUNT OF EACH COLORANT INTO THE PRODUCTION SYSTEM
5. A SYTEM TO CONTROL THE OPERATION OF THE PRODUCTION SYSTEM AND TO MONITOR THE COLOUR QUALITY OF THE PRODUCT
6. A MANAGEMENT SYSTEM TO MONITOR THE INFORMATION FLOW IN THE INTEGRATED COLOUR PRODUCTION SYSTEM

Figure 1 An Integrated Colour Production System